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REVIEW ARTICLE

MITIGATION OF NOISE POLLUTION IN URBAN AREAS BY STRATEGICALLY PLANTING TREES AND SHRUBS

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ABSTRACT

Noise is universally recognized as a significant source of environmental degradation in every culture. This paper provides an assessment of the literature on the detrimental impacts of noise pollution on the well-being of individuals. There is an introduction providing a broad definition of noise, followed by a discussion of the effect of noise pollution, the harmful consequences of noise on human health, and the techniques used to reduce noise pollution. In conclusion, this article reviews how this type of pollution can be mitigated and refers to vegetation's aesthetic, ecological, and other benefits beyond its noise-blocking properties. The results of this research are significant on a personal and societal level in light of the detrimental impacts of noise pollution, and they may be helpful as a guide for planning in locations where such consequences are likely to materialize.

KEYWORDS

Noise pollution, Traffic noise, environmental hazard, Plantation.

1. INTRODUCTION

According to the World Health Organization, noise pollution is nowadays the third most hazardous environmental type, preceded only by air (gas emission) and water pollution (Khilman, 2004). Pollution in large cities is an ever-growing problem since the urban environment is becoming increasingly crowded, busy, and noisy. Since the seventies, "noise" has mainly been considered a significant problem of annoyance in cities. Cities with growing populations, urbanization, and industrialization exacerbate and disperse environmental pollution (Ratte et al., 2013; Ozdemir et al., 2014; Iqbal et al., 2022; Dilawar et al., 2022). Migration from rural to urban regions, expansion of cities, infrastructure development, population growth, and urbanization are significant contributors to motorization and the subsequent rise in urban pollution levels (Mishra et al., 2010). Environmental pollution is caused by several undesirable and unwanted causes, one of which is noise, which degrades the quality of life by interfering with activities such as concentration, communication, relaxation, and sleep (Haq et al., 2014). The World Health Organization ranks noise pollution as the third most dangerous in urban areas, behind air and water pollution (WHO). The World Health Organization (WHO) has calculated that traffic noise might be responsible for over one million healthy years lost yearly to any unwanted sound affecting human health or the environment. It is a pervasive problem in urban areas, and various sources, including traffic, industrial activity, and construction, can cause it. Noise pollution can significantly impact human health, causing hearing impairment, sleep disturbance, and cardiovascular problems. Studies have also linked noise pollution to psychological problems, such as anxiety and depression. In addition to the adverse effects on human health, noise pollution can also affect wildlife by disrupting communication, nesting behavior, and migration.

2. EFFECT OF NOISE ON HEALTH

2.1 Noise and Sleep Disturbance

The disruption of sleep by noise is supported by both empirical and subjective evidence (Ohrstrom et al., 1988). There is a direct correlation between the volume of ambient noise and the number of times you awaken during the night. An increase in nightly and cumulative sound exposure leads to habituation. However, lab research conducted over 14 nights of maximal noise exposure found no habituation (Ohrstrom et al., 1989). If there are more than 50 noise episodes per night, with a maximum level of 50 dBA or greater indoors, sleep will be objectively disrupted. Outside noise levels are only mildly correlated with sleep disruption. In the Civil Aviation Authority Study conducted near Heathrow and Gatwick airports, noise levels did not increase, but the share of total sleep disturbance that might be attributed to noise did. A symptom reporting or attribution effect, rather than actual noise effects, was hypothesized in the study.

After that, actigraphy research was conducted near four UK airports to examine how different levels of airplane noise affected sleep quality throughout 15 consecutive nights (Horne et al., 1994). None of the aircraft

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noise events were associated with awakenings detected by actigraphy, and the chance of sleep disturbance with aircraft noise exposure of 82 dB was negligible. However, there was a strong association between sleep EEGs, actigraphy-measured awakenings, and self-reported sleep disturbance. This study is likely more representative of real-world conditions than those conducted in the lab on people who were not previously exposed to aircraft noise. However, the actigraph's reliability as a sensitive indicator of sleep disruption is in dispute. The amplitude of your pulse in your fingers, your heart rate, and the frequency of your bodily movements may all rise if you sleep with a noisy roommate. There may be daytime repercussions as well: after a night of sleep disrupted by road traffic noise, people reported poorer sleep quality, mood, and performance in terms of response time. It would appear, then, that although some habituation may occur, notably for heart rate, to sleep interruption by noise, total habituation does not.

2.2 Noise exposure and performance

Research, mostly in controlled environments, shows that noise exposure reduces productivity (Loeb, 1986). When speech is played while a subject reads and remembers verbal material, performance may suffer; however, this impact is not observed with non-speaking noise (Salame et al., 1982). The effects of "irrelevant speech" are the same, no matter how loud or how important the speech is. Since "irrelevant speech" can get in the way of complex mental tasks, it makes sense that reading, which relies on memory, may also be harder. The effects and after-effects of noise exposure depend on how much people think they can control and predict noise. Glass and Singer, found that tasks done while there was noise did not affect them, but tasks done after the noise was turned off did (Glass and Singer, 1972). This effect was lessened when the subjects thought they could control the noise. In fact, just thinking about loud noise can hurt performance, even if it is a system. Exposure to noise causes physical activation, including increases in heart rate and blood pressure, peripheral vasoconstriction, and peripheral vascular resistance. Brief noise exposure has rapid habituation, but prolonged noise habituation is less certain (Vallet et al., 1983).

2.3 Occupational Study: Noise and High Blood Pressure

Blood pressure studies in the workplace provide the most compelling evidence for the impact of noise on the cardiovascular system (Thompson, 1996). Several studies have found that blood pressure was higher among those who lived near Arlanda airport in Stockholm, where the average level of aircraft noise was at least 55 dBA and the maximum level was above 72 dBA (Babisch et al., 1988). In conclusion, community-based studies have linked environmental noise to elevated blood pressure and suggest it may be a modest risk factor for cardiovascular disease (Relative Risk 1.1–1.5) (Rosenlund et al., 2001; Babisch et al., 1999 Babisch, 2000). Catecholamine secretion is stimulated, and cardiac dysrhythmias may be triggered by sudden, strong noise exposure. Continuous cardiac monitoring patients have not shown any changes in heart rate due to noise in studies of the effect of speech noise in coronary care units or studies of noise from low-altitude military flights (Brenner et al., 1993).

2.4 Endocrine response to noise

Some studies have found a connection between occupational exposure to loud noise and increased levels of noradrenaline and adrenaline (Cavatorta et al., 1987). One study found that workers whose ears were protected from loud noise experienced a reduction in catecholamine production. Cortisol levels were found to be higher in certain studies regarding noise, but not all of them. Although there is some inconsistency between research, the overall pattern of endocrine responses to noise suggests that noise is a stressor that excites short-term physiological reactions.

2.5 Noise annoyance

The most common and studied subjective reaction to noise is annoyance, which can also include moderate wrath and terror if the listener thinks they are being intentionally harmed (Brandenberger et al., 1980). Noise is annoying because it invades one's peace, yet how someone interprets a sound has a lot to do with whether or not they find it annoying. The degree to which noise disrupts regular activities is likely a precursor to and driver of annoyance (Cohen et al., 1981). There appears to be a dose-response association between noise levels and discomfort in investigations of traffic and airline noise (Gunn, 1987; Taylor, 1984). Aircraft noise has the most negative impact on speech-related activities such as having a conversation, watching television, or listening to the radio. In contrast, nighttime traffic noise is the worst problem for getting a good rest.

2.6 Community noise survey acoustic predictors

The loudness or perceived intensity of noise is one of the main things that makes it annoying. The duration of a sound, its tone variation, and its intensity all contribute to its overall loudness. There is conflicting research regarding the relative weight of duration, frequency, and incident count in establishing annoyance (Schulz, 1984). Noisiness at higher frequencies is more bothersome than that at lower frequencies (Miedem, 2001). Most community studies of noise find that vibrations are essential elements in assessing irritation, mostly because they are typically experienced through other senses in addition to hearing, making them a complement to loud sounds. After adjusting for noise level, Fields, 1984 found that people are more bothered by noise if they are more afraid of the source of the noise, more sensitive to the noise, more confident that the authorities can control the noise, more aware of the source's non-noise impacts, and less convinced that the source is essential.

3. Noise Sources

1. Toys and Play stations.
2. Mechanical household, kitchen, office, and educational appliances.
3. Entertainment: Radio, TV, music systems, bands, speakers, cinemas, and personal audio systems such as headphones, earphones, and Bluetooth devices.
4. Communication devices such as mobile phones.
5. Transport vehicles: Motor-wheeled vehicles that are used personally for commuting, public transport vehicles such as buses, trains, aircraft, and goods transport vehicles such as trucks, freight trains, and cargo aircraft.
6. Mechanical equipment: Hammers, grinders, mowers, mixers, fans, air coolers and air conditioners.
7. Large machinery: Movers, drills, machines, and vehicles used in the construction and maintenance of houses, apartments, office buildings, schools, colleges, and factories.
8. Deforestation or urbanization: This is an indirect contributor to noise. Deforestation leads to increased construction of houses, commercial areas, industry, roads, and traffic, which ultimately leads to more noise in a previously quiet area.

The effects of noise pollution on animals are universal; they either become more vocal or more reticent. As the circumstance requires, they get angry, lose focus, and seek refuge elsewhere, either momentarily or permanently (Bjork, 1986). Both the human body and the mind are negatively impacted by noise pollution. Noise exposure causes psychomotor effects by making people more stressed, making it hard to sleep, making it hard to concentrate, making people angry and violent, and causing the heart rate to go up, which is often seen with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Fields, 1992). Noise-induced hearing loss and tinnitus have both been linked to prolonged exposure to loud environments (NIHL). It can be This is particularly prevalent with traffic, occupational, and recreational noise, where exposed individuals were reported to have substantial NIHL (Fields, 1992). Pregnant women and toddlers who accompany their parents to places like construction sites and factories are particularly vulnerable to the effects of loud noises, which can cause both short-term and long-term hearing loss. The earlier a kid is exposed to noise, the sooner they will get Noise-Induced Hearing Loss (NIHL) and other non-auditory issues (Rosen and Oline, 1965). If the results of a newborn's hearing test are normal, we tend to forget about the baby's hearing and any potential issues as they develop. Hearing loss is typically identified after an observant parent or educator notices a lag in development or poor academic performance or after the child or adolescent themselves bring it to their attention. Hearing loss at that point is typically permanent, getting worse with age and exposure to even mild noise.

4. Traffic Noise

The most significant noise source in cities is vehicles and road traffic, forcing residents to escape the clamorous roadsides and take refuge in quieter spots. One of the most crucial noise types is urban traffic noise, and naturally, it is considered more interfering than the other types of noise (Zannin et al., 2003; Mishra et al., 2010). In recent years, road traffic noise has played a dominant role in environmental noise pollution, which can adversely affect communities' health. (Chepesiuk, 2005; Bluhm et al., 2007; Mehdi et al., 2011). Traffic noise is generated by a mixture of

different vehicles, light and heavy, running in the streets of a city or the different lanes of a highway. Cars are increasingly invading the urban landscape, contributing to higher noise pollution than any other man-powered engine. Therefore, most of today's research on noise control is focused on noise from transportation, particularly emphasizing urban traffic (Ouis, 2001), as described in the figure below. A group researchers found, based on their survey, that 68 % of people reported the problem of stress due to traffic noise pollution (Mishra et al., 2010).

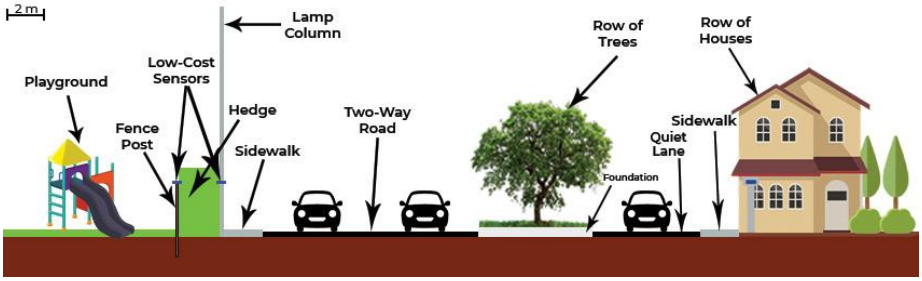

Figure 1: A common complaint about high-speed roads is the noise from traffic. Noise can be partially deflected and absorbed by a combination of structural and vegetative practices. (Picture Credit: Muhammad Minhal Ali)

5. Use of Environmental Sound Barriers

To protect residential, recreational, and other vulnerable areas beside a road, an environmental sound barrier combines the roles of a visual screen and a noise barrier. There is a substantial body of literature devoted to the modeling and engineering design of noise barriers (Li and Wong, 2005a; Arenas, 2007a). In addition, several researchers have focused their efforts on developing more effective noise barrier designs and predicting their performance (Li and Wong, 2005b). Depending on their configuration and height, environmental noise barriers can reduce A-weighted noise levels by 3-7 dB on average. Having a barrier tall enough to impede the line of sight from the road to the receiver can reduce the signal by 5 dB if the barrier surface density is greater than 20 kg/m2 and by an additional 1.5 dB for every additional meter of height.

However, in fact, the maximum attenuation that environmental barriers can achieve is around 20 dB for a single barrier and 25 dB for a double barrier. There should be at least eight times as much space between the barrier and the receiver (USDT, 2001). Height, length, material type, construction technique, maintenance, and other aspects all contribute to the overall price of a noise barrier. You can find some examples of the typical costs for different environmental barriers in the literature (Arenas, 2006). Unfortunately, when barriers are employed in the field, the acoustical performance is typically degraded by meteorological influences such as wind or temperature gradients above the barrier. Studies done in the past have demonstrated that vegetation has a role in mitigating the effects of wind (Van Renterghem et al., 2002).

A smart design must account for the fact that a barrier should require minimal maintenance, other than cleaning and damage repair, over a long period. It is preferable to have a service life of 40 years, with only minor repairs needed after the first 20 years. Hence, it is important to carefully pick the materials used in the building of barriers, especially in regions that are prone to extreme weather. A wide variety of materials, including but not limited to earth, concrete, masonry, wood, metal, and plastic, can be used to build noise barriers. Up until 1998, the majority of walls erected in the United States were found to be composed of concrete or masonry blocks, with heights ranging from 3 to 5 meters; only around one percent of these walls were found to be formed of absorptive materials (USDT, 2000). An example of an environmental barrier is an earth mound.

In fact, an earth mound, which is sometimes called a berm, is a noise barrier made of soil, stone, rock, or rubble that runs along a highway and is often landscaped to protect nearby land users from noise pollution. Using earth mounds can save money because they can be built with scraps left over from other parts of the project (given enough space, of course). According to a life-cycle cost analysis, earth mounds are the cheapest option for building a noise barrier (Morgan et al., 2001). Because it may be shaped to blend into the landscape more organically than any vertical construction, and given that it can support vegetation, its appearance is considerably improved in most rural contexts; an earth mound is an obvious choice to lessen the visual effect. Both pedestrians and drivers will appreciate the natural beauty of an earth mound enhanced by plants. Selecting hardy evergreen species (native plantings are preferred) that require little maintenance is important when choosing plants to use in conjunction with a barrier. Despite the fact that practical and theoretical assessments have generated varied results, some research suggests that earth mounds may provide better sound absorption than vertical walls of the same height when it comes to acoustic performance (Arenas, 2007b).

6. Effect on Ecosystems

Several studies have looked at how roadways affect wildlife and their habitats ecologically (Ramp et al., 2005; Ramp et al., 2006). It is common knowledge that traffic accidents involving vehicles on roads account for a large number of annual deaths. In addition, highways can be a demographic danger because they create barriers to movement, cutting off people from their natural habitats as well as potential mates and food supplies. This barrier effect is proposed as the most significant ecological consequence of roads with vehicles in an assessment of the ecological effects of highways published by (Forman and Alexander, 1998). Sound barriers may help lower collision-related fatalities, but they may make matters worse for vulnerable animal populations. This feature may impact several species in the vicinity of a very long sound barrier. Ecoducts, artificial structures erected on a crossroad to link natural areas on each side, are one solution to this problem.

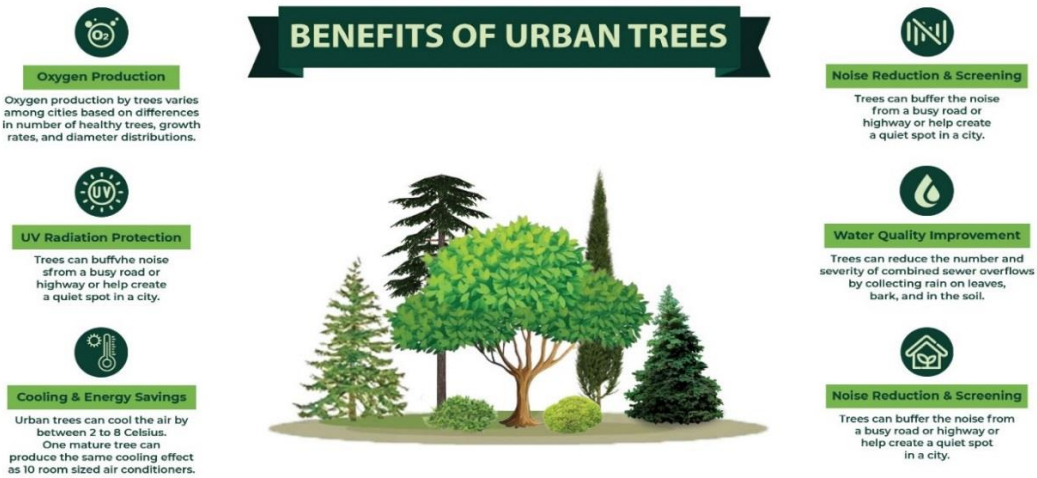

Figure 2: Benefits of planting Trees and Shrubs. (Picture Credit: Muhammad Minhal Ali)

One potential ecological issue is presented by birds colliding with see-through sound barriers (usually composed of thermosetting acrylic polymers). For some countries, this could have a major impact on the number of birds killed on the roads (Reijnen et al., 1997). The benefits of planting trees and shrubs in urban areas have the following effects as mentioned in an image below; some benefits included are as follows:

Noise absorption: Trees and shrubs can absorb noise by converting sound waves into heat energy. This process, known as sound absorption, reduces the noise that reaches the ground level.

Noise reflection: Trees and shrubs can also reflect noise, mainly if they are located in strategic positions. This process, known as sound reflection, can reduce the amount of noise that enters buildings and other structures.

Barrier effect: Trees and shrubs can also act as a physical barrier, reducing the amount of noise that enters a particular area. This effect is beneficial for noise generated by traffic or industrial activity.

Psychological benefits: In addition to the noise reduction benefits, vegetation can also provide psychological benefits, such as improving an area's visual appeal and reducing stress levels.

6.1 The established principles of plant belts

Reduction of noise with plants, when sufficient area is provided in the urban ecosystems, is of great importance. The principles that are needed to be successful in establishing a noise belt area could be summarized such as in the following:

- The minimum planting area should be 5m wide. This amount could be as much as up to 30m.
- The plants subjected to use should be selected from natural flora or the appropriate varieties compatible with the natural flora.
- The “evergreen” plants should be used primarily. -The plants should be planted uprightly in the noise direction.
- The plants should have been planted as close as possible to each other, and the distance between the two plants should be appropriate for growing conditions.
- Plants that are longer, more extensive, hard textured, intensive leaf-branch and apical tissue reaching the ground should be preferred.
- The plant groups, which consist of different heights of trees, shrubs, and bushes, should be used.
- The longer plants should be planted to the back side of shorter plants, and the distance between to plants should be increased as much as possible.

The plants consisting of bushes and coniferous which are more than 5m, can block the noise. The result would be better in the case of a position where the plant belt is placed as close to the source of the noise and as far as the area that is wanted to be protected. It will be more efficient than putting the plant belts together with noise barriers and soil walls to block the noise (Onder and Kocbeker, 2012).

6.2 Noise Abatement by Vegetation

Trees and shrubs can be used effectively as noise-reducing media for decreasing stress because of intolerable noise. Trees and shrubs can absorb unwanted sounds and support animals and birds for their desirable sounds. Plantations and green belts around the roadside will prevent the noise from reaching the buildings. It will increase the beauty of the road and give many other scientific and geological benefits. In urban areas, noise pollution can be a significant problem. It can lead to stress, anxiety, and even physical health problems. However, one solution to this problem is to use plants, trees, and shrubs to help reduce noise levels. These natural sound barriers can be an effective and aesthetically pleasing way to create a quieter and more peaceful urban environment. This article will explore some of the best plants, trees, and shrubs that can help reduce noise pollution in urban areas.

Evergreen Trees: Evergreen trees, such as conifers, can help absorb sound waves due to their thick foliage and rough bark. They can also provide year-round protection against noise pollution. Species such as Cedar, Pine, and Spruce are all excellent choices for reducing noise pollution.

Deciduous Trees: Deciduous trees, which lose their leaves in the fall, can also effectively reduce noise levels. While they may not provide year-round protection, they can still help block out noise during the summer when the leaves are on them. Trees such as Oak, Maple, and Birch are all excellent choices for reducing noise pollution.

Shrubs: Shrubs are another excellent option for reducing noise pollution in urban areas. They are typically more compact than trees and can be used together to create an even more effective sound barrier. Species such as Privet, Boxwood, and Holly are all excellent choices for reducing noise pollution.

Bamboo: Bamboo is a fast-growing plant that can be a great option for reducing noise pollution. It is known for absorbing sound waves and can be planted in dense clumps to create an effective sound barrier. Species such as Black and Golden Bamboo are good choices for reducing noise pollution.

Hedges: Hedges are a great option for reducing noise pollution in urban areas. They are typically tall and dense and can be used to create a barrier between a busy road or noisy area and residential or commercial property. Species such as Leyland Cypress, Arborvitae, and Japanese Holly are all excellent choices for reducing noise pollution.

In addition to these plants, it is essential to consider other factors when creating a natural sound barrier. Factors such as the plants' height, density, and distance from the noise source can all impact their effectiveness. Choosing appropriate plants for the local climate and soil conditions is also essential.

In conclusion, plants, trees, and shrubs can effectively reduce noise pollution in urban areas. We can create a more peaceful and enjoyable urban environment by creating natural sound barriers. Whether to choose evergreen or deciduous trees, shrubs, bamboo, or hedges, the right plants can significantly reduce noise pollution. Table 1 describes the trees and shrubs that are used to reduce noise pollution.

Table 1: Plant Species used as a Sound Barrier.

Trees	Reference	Shrubs	Reference
Arbor vitae	Lanphear, 1971	*Tecoma grandlfiora*	Yufu, 2013
Bamboo	Huda et al., 2012	*Nerium odorum*	Joshi et al., 2020
Fir	Maleki et al., 2011	*Photinia viburnum*	Fan et al., 2010
Spruce spp	Van Renterghem, 2003	*Jasminum humile*	Eric and Kathy, 2001
Laurel trees	Martine et al., 2006	*Murraya paniculata*	Pathak et al., 2008
Prunus laurocerasun	Biocca et al., 2019	*Broussonetia papyrifera*	Gini et al., 2012
Cupressus atlantica cv. Glauca	Edogan et al., 2009	*Ilex cornuta*	Li Yanan et al., 2000
Illicium anisatum	Wang et al., 2014	*Thuja orientalis*	Fredianalli et al., 2019
Pinus sylvertris	Ozer et al., 2008	*Pyracantha coccinea*	Mutlu et al., 2012
Populous nigra	Ozer et al., 2008	*Cornus alba*	Esmeray et al., 2021
Tamarix tetrandra	Irmak et al., 2008	*Pittosporum coccineae*	Gratani et al., 2013
Eucalyptus camaldulensis	Multidiadu et al., 2018	*Cornus alba*	Esmeray et al., 2021
Dalbergia sissoo	sharma et al., 2021	*Pittosporum tobira*	Gratani et al., 2013
Terminalia arjuna	Pandey et al., 2015	*Berberis thunbergii*	Onder et al., 2012
Erythrina indica	Li et al., 2006	*Euonymus japonicus*	Zhu et al., 2019
Largertoemia spp.	Juminga et al., 2016	*Spiraea vanhouttei*	Harte et al., 1997

7. Challenges and Strategies in Planting Trees and Shrubs for Noise Reduction

Despite the numerous benefits of planting trees and shrubs for noise reduction, several challenges are also involved. Some of the challenges include the following:

Space constraints: Urban areas often have limited space, and finding suitable locations to plant trees and shrubs can be challenging.

Maintenance: Trees and shrubs require watering, pruning, and pest control. This maintenance can be time-consuming and expensive.

Species selection: Selecting the correct species of trees and shrubs is critical for effective noise reduction. Some species are more effective than others, and the wrong species can have little or no impact on noise reduction.

Cost: Planting trees and shrubs can be expensive, especially in urban areas where land costs are high.

To overcome these challenges, several strategies can be employed. These strategies include the following:

Strategic planting: Trees and shrubs should be planted strategically, focusing on areas with the highest noise levels. This approach can maximize the noise reduction benefits of vegetation.

Species selection: Selecting the correct species of trees and shrubs is critical for effective noise reduction. Species that are effective in reducing noise levels should be selected.

Maintenance: Proper maintenance of trees and shrubs is critical for their effectiveness in reducing noise pollution

7.1 Choice of Species

Each species has its own climatic and edaphic requirements. So, species should be selected according to their ecological zone; otherwise, they may be a failure. The following considerations should be adopted while selecting species. Attenuation of up to 8 dB(A) for 100-foot deep tree belts can be achieved for dense 40 – 50 feet-high plantings with a visibility of about 50 feet or less. The following species are recommended for roadside planting and green belts.

- A tree should be medium-sized and widespread with a more oversized crown, while shrubs reduce more noise than trees, so emphasis should be given to it where possible.
- Plants should have denser branches with maximum leaf area.
- Harmful plants for human health should not be selected, such as Theretia, Butea, and Nerium spp.
- Trees and plants to be planted should be free from diseases and have a moderate rate of growth, but we cannot select fast-growing species due to their shorter rotation.
- Plants should be wind prone; neither should their branches break nor be uprooted because this will cause problems and hinder traffic.
- Thorny plants should not be planted along the roads because thorns damage vehicle types and cause passerby injury.
- In problematic areas, any species should be grown within the area. For e.f. Ficus spp.

8. Conclusion

This paper highlights the potential of green infrastructure for reducing noise pollution in urban areas. The study has provided evidence that planting trees and shrubs can effectively reduce noise levels and improve the overall acoustic environment in urban areas. The paper suggests that careful planning and management of green infrastructure can provide a cost-effective and sustainable solution for reducing noise pollution in urban areas. There is a need for more research to be conducted further to understand the relationship between green infrastructure and noise reduction. Further studies should also explore the potential of incorporating other green infrastructure measures such as green roofs, green walls, and water features in noise reduction strategies. Finally, policymakers and urban planners should consider incorporating green infrastructure as a key component in their urban planning strategies to mitigate noise pollution. By prioritizing integrating green infrastructure, urban areas can become healthier, more sustainable, and enjoyable places to live.

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